15. Slow sand filter design

Sand Filter Design

Slow sand filtration is a simple and effective technique for purifying surface water. It will remove practically all the turbidity from water, together with virtually all harmful eggs, protozoa, bacteria and viruses without the addition of chemicals and may frequently be constructed largely with local materials.

A slow sand filter consists basically of three different layers within a filter-box. These layers are from bottom to top: the underdrainage system, the gravel layer and the sand. It is only the sand which plays any part in the treatment process.

The underdrainage may consist of:

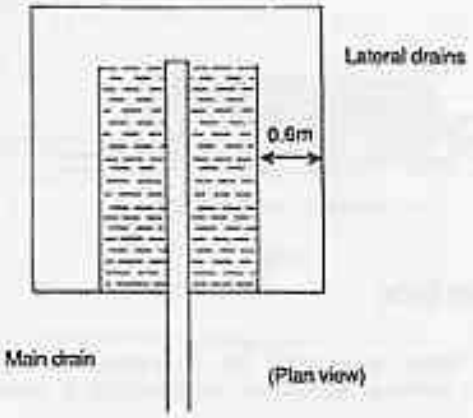
* perforated pipes of asbestos cement
* porous or perforated unglazed pipes
* perforated pipes of PVC

or of

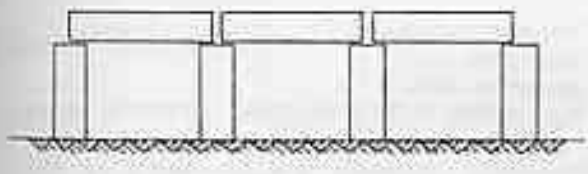
* concrete tiles
* household bricks
* large gravel (40 - 100mm)

If pipes are employed, a series of lateral drains (60mm diameter) are connected to a main drain.

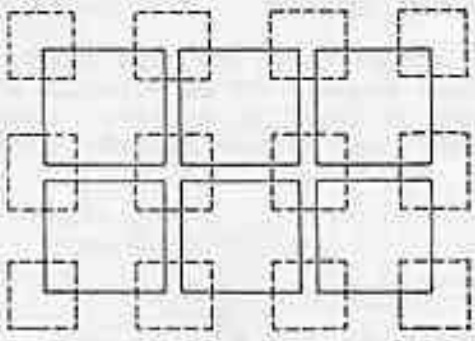
Perforations of 2 to 4mm diameter are made on the underside of the lateral drains at intervals of 150mm.
Cross-sectional area of main drain = sum of cross-sectional areas of all lateral drains.



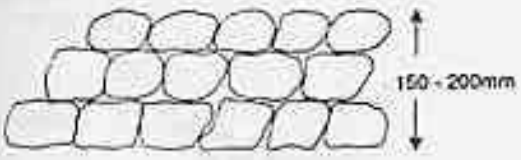
Standard bricks.



Concrete tiles - whole tiles are set on quarter-tiles as illustrated.



Large gravel (40 - 100mm).



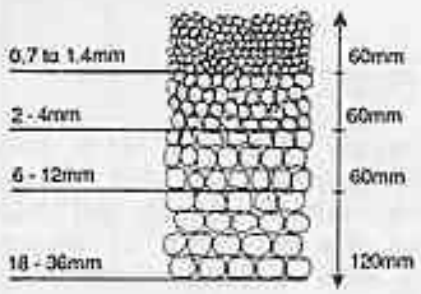
The underdrainage should not be closer to the wall than 0.6m.

SLOW SAND FILTER DESIGN

The Gravel Layer

The gravel layer is arranged in four graded levels. All gravel must be clean.

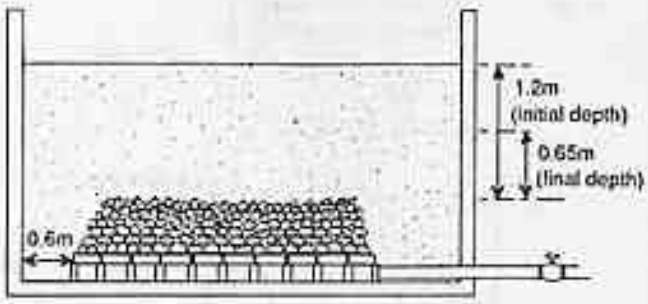
The gravel layer should not be closer than 0.6m to the walls. This means that any water which runs quickly down the walls and does not filter through the sand layers (ie, it 'short-circuits' the system) must pass through some depth of sand before entering the gravel and underdrainage.



The Sand Layer

Is characterized by:

Effective Size (E.S.) - mesh diameter (mm) of a sieve which retains 90 per cent of the sand.



Sand, gravel and underdrainage

Uniformity Coefficient (U.C.) - mesh diameter (mm) of a sieve which retains 60 per cent of the sand, divided by the effective size.

E.S. - between 0.2mm and 0.4mm

U.C. - less than 3.0, preferably less than 2.0

Suitable sand is usually easy to find locally. If any grading is necessary, it is normally sufficient to remove only the coarsest grains and the very finest grains.

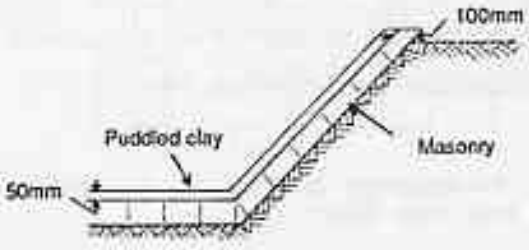
Filter Box

The filter box may be constructed either with vertical sides or with sloping sides.

If designed to have vertical sides it may be constructed of either:

- mass-concrete
- ferrocement
- masonry
- reinforced concrete

During construction the wall must be roughened where it will be in contact with the sand in order to prevent short-curculting (see section on the gravel layer).

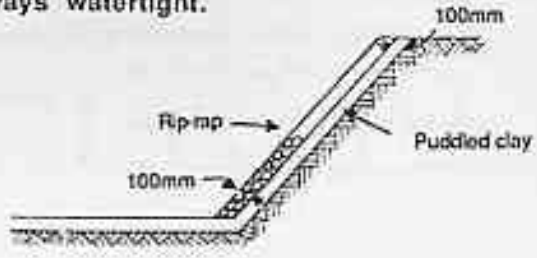


If the filter box is designed to have sloping sides it may be constructed either of:

- mass-concrete
- masonry
- puddled clay
- rip-rap

Commonly, masonry will be employed and the system made watertight by adding a layer of puddled clay

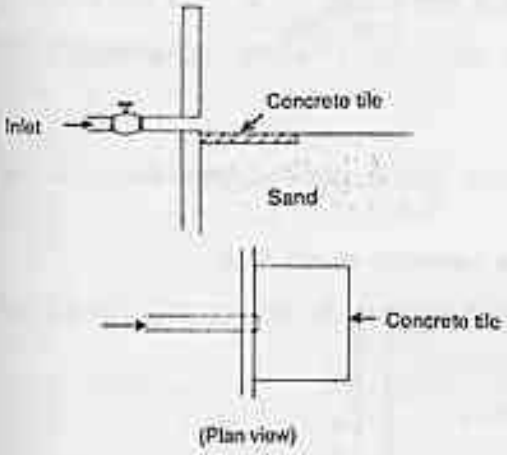
Sloping walls are simpler to construct and can usually be made with locally available material but cannot be guaranteed to be always watertight.

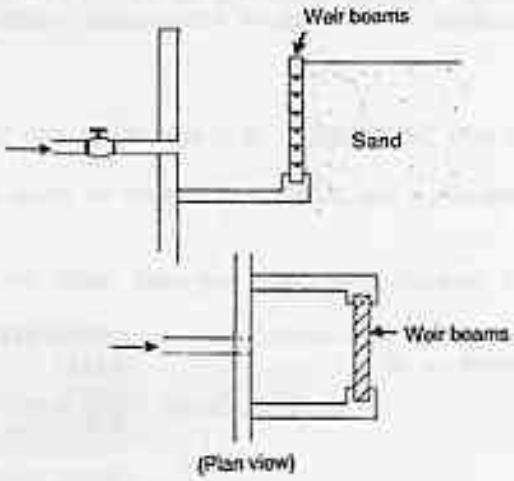


Inlet Arrangements

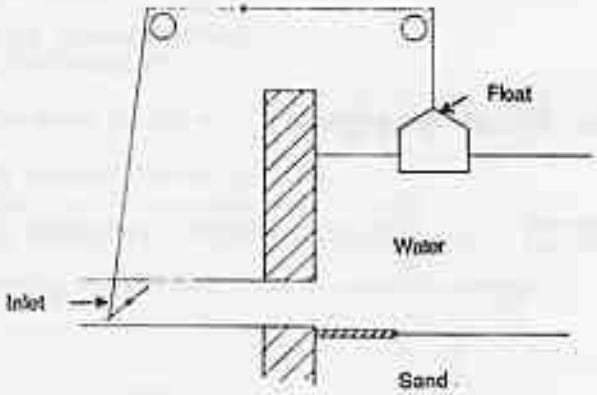
There are two main types of inlet arrangement.

The concrete tile is a splash tile to prevent water falling directly onto the sand-bed and eroding it.





The inlet is controlled either by a hand-operated gate valve or by a float-controlled butterfly valve.

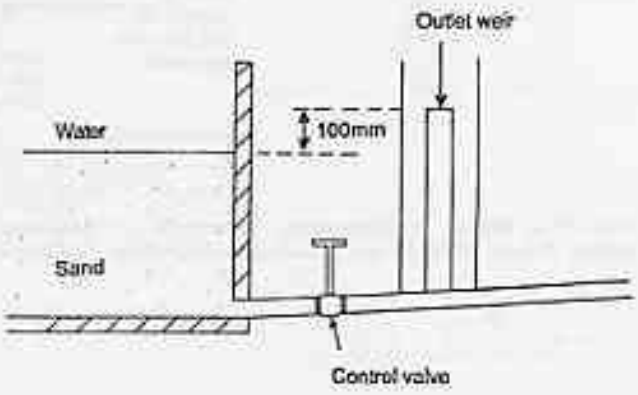


Water Reservoir

This is normally maintained at a constant depth of between 1.0m and 1.5m.

Outlet Arrangement

The outlet flow is maintained at the design flow rate by a hand-operated gate valve which is adjusted every day. It is essential to provide an outlet weir which is above the height of the sand bed.



SLOW SAND FILTER DESIGN

The size of the filter

The size of a slow sand filter is determined by several factors.

For example:

Population of 1000 with water consumption of 100 litres/capita day.
Wastage can be assumed to be 30 per cent of production.
Therefore - total daily production needs to be: 1000 x 100 x $\frac{100}{(100-30)}$ = 143 000 litres/day

= 143 m^3/day

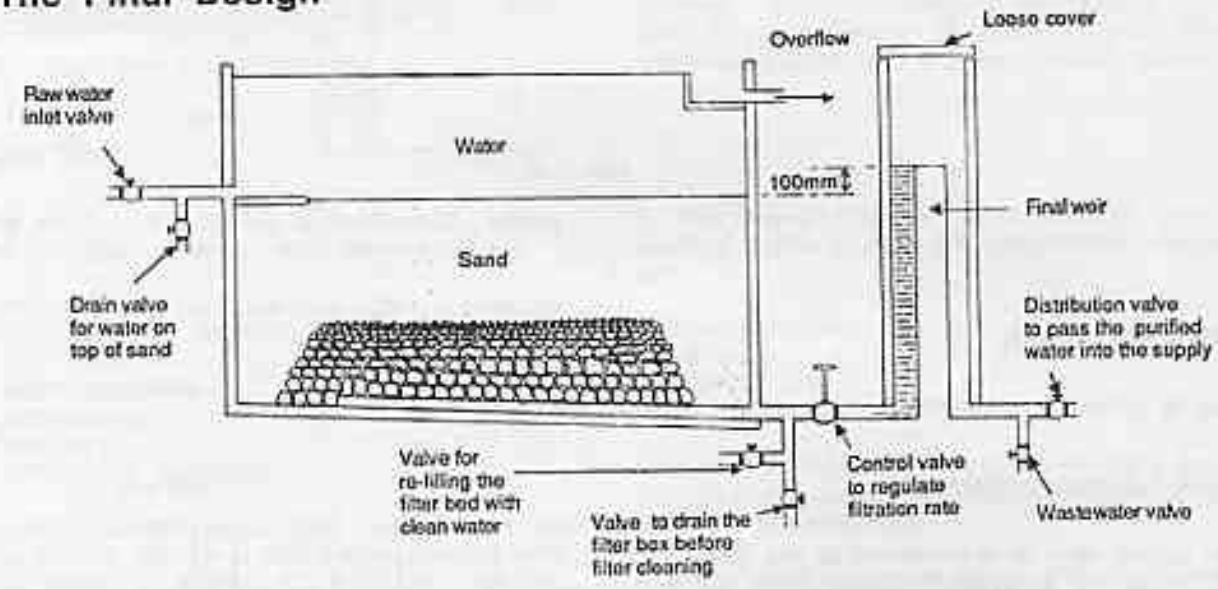
The rate of filtration is 2.4m^3/m^2d (=0.1m/h)

Therefore - the filter tank needs to have an area of: $\frac{143}{2.4}$ **= 56m^2 (7m x 8m)**

Two parallel filters are required, each 7m x 4m, with a common divide wall.

Overall filter tank height is made up of:	above level of water	- 0.3
	water	- 1.0
	sand	- 1.2
	gravel	- 0.3
	underdrainage	- 0.15
	foundations	- 0.15
		3.10 metres

The Final Design



Ken Ellis, WEDC, Loughborough University of Technology, UK.
Claire Purvis, WEDC, Loughborough University of Technology, UK.

21. Slow sand filters (2)

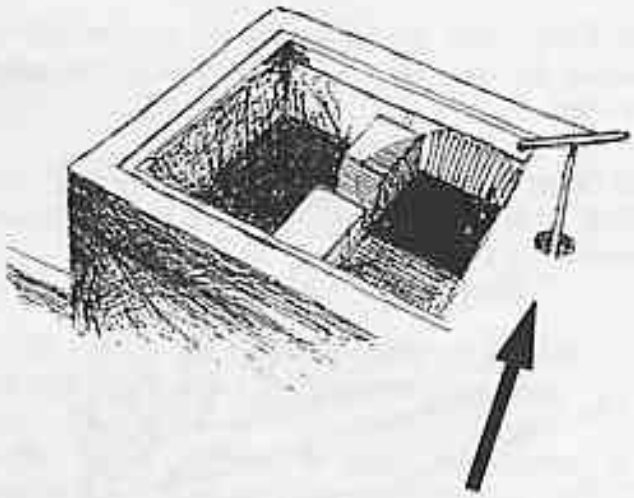
Operation and maintenance

The effectiveness of slow sand filters depends very much on the style of operation and maintenance. A major advantage of this process is the limited number of tasks which must be performed, **but these must be carried out correctly.** (For design notes, refer to *Technical Brief No. 15.*)

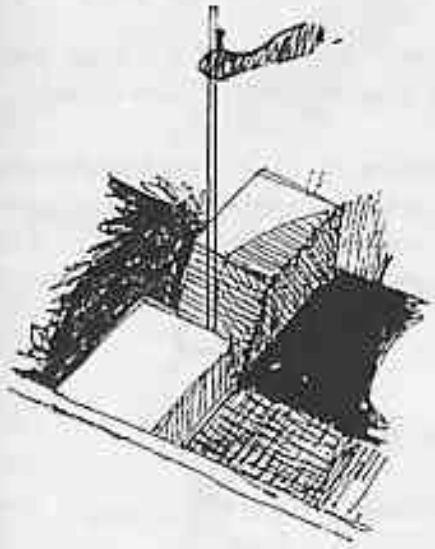
Daily tasks

1. Ensure the depth of water in the reservoir above the sand is near the maximum. The level must be just at or very slightly below the overflow. **This level should not be allowed to fall.**

2. Adjust the treatment rate and the design flow by slightly opening the control valve (or slightly closing it if it was previously incorrectly set). The control valve is the outlet valve between the filter outlet and the final weir.



Adjust the outlet valve



Dip the water flow

The correct flow rate can be accurately judged by dipping the depth of water flowing over the final weir, or by checking the water depth over the V-notch weir set on the outlet weir.

3. Observe the quality of the source water and of the filtered water. It is also helpful to check for any odour in both source and filtered water.

4. Note, in the records, the flow rate, condition of source and filtered waters and any unusual occurrences. Unusual occurrences might include unseasonal weather conditions, development of algae in the filter, rising *schmutzdecke* (filter-skin) or the illness of any of the operators.

Scraping the filter

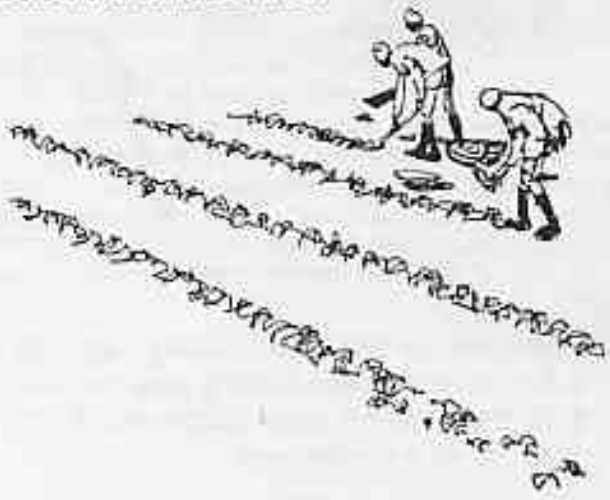
Scraping becomes necessary when, with the maximum head of water available above the sand and the outlet valve fully open, it is not possible to obtain the design flow.

(When scraping the filter, it is essential to take measures to control the personal habits of the workers. There should be no spitting, urinating or defecating. Tools should be disinfected.)

1. Commence the scraping (or filter cleaning) operations by closing the inlet valve at the end of the day and allowing the filter to drain overnight.

2. Early next morning, run off any remaining water by opening the drain valve at the sand surface.

3. Continue to drain surface water through the filter until the level of water is about 100mm below the sand surface.



Gather the schmutzdecke *into ridges*

6. Remove the ridges of dirty sand and *schmutzdecke* from the filter. (See right.)

7. Smooth out the surface of the sand. Adjust the level of the sand surface drain and of the final weir if necessary and possible.

8. **Refill the filter from the bottom** until there is a depth of 150-200mm of water above the sand then stop filling from the bottom and resume filling in the normal manner.

Swab down the filter walls

4. Swab down the walls of the filter box and remove any attacked algae. (See above.)

5. Begin scraping by using broad-bladed shovels or hoes to gather the *schmutzdecke* and any dirty sand into long ridges. The removal of a 25mm depth is usually sufficient. (See left.)

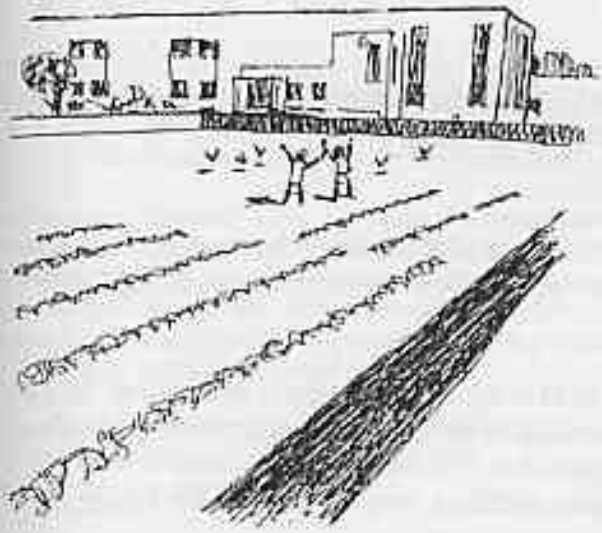
Carry away dirty sand

Do's of slow sand filter operation

During filter cleaning:

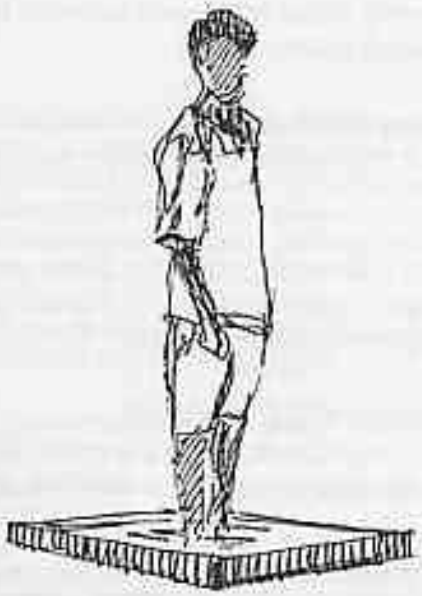
- ***Do*** make sure that the cleaning operation is carried out quickly — one day is usually sufficient.

- ***Do*** make sure that there is a bath tray of clean water for all the personnel involved to walk through each time they enter the filter. Footwear should be provided.



Scare birds away from the filter

- ***Do*** refill the empty filter from the bottom.



Walk through a bath tray of water

- ***Do*** control the personal habits of workers in the filter. No spitting, urinating or defecating.

- ***Do*** make sure that all birds are continually scared away from the exposed sand.

Don'ts of slow sand filter operation:

- ***Don't*** dig up the whole of the sand bed during cleaning.

- ***Don't*** allow the level of the water in the reservoir to fall.

- ***Don't*** operate at varying rates.

- ***Don't*** allow people who are unwell to enter the empty filter during cleaning.

- ***Don't*** clean more than one filter at a time.

- ***Don't*** allow birds to foul exposed sand during cleaning.

SLOW SAND FILTERS (2)

General points

The following notes relate to *Technical Brief No.15, Slow Sand Filter Design*, and are intended to clarify design points.

1. The Gravel Layer

Instead of four layers of graded gravel illustrated, it is possible to use only a three-layer gravel system:

Top layer: 100mm depth of 1-1.5mm gravel
Middle layer: 100mm depth of 4-6mm gravel
Bottom layer: 100mm depth of 16-23mm gravel

2. The Uniformity Coefficient

The Uniformity Coefficient is the mesh size of a sieve in mm which retains 90% of the sand divided by the mesh size of a sieve in mm which retains 40% of the sand.

3. Inlet and outlet control

(i) The function of the inlet control system is to maintain a constant head of water above the sand.
(ii) The function of the outlet control system is to regulate the flow of water to the design rate.

4. Removal of viruses

A minimum depth of sand of 600mm is recommended to ensure the complete removal of viruses.

References: Poynter, S.F.B. and Slade, J.S., *The removal of viruses by slow sand filtration*, Prog. Water Technol., 9,75, 1977.
Windle-Taylor, E., *The removal of viruses by slow sand filtration*, Rep. Results Bact. Chem. Biol. Exam. Land. Waters, 44,52, 1969-70.

5. Eliminating wall effects

In order to eliminate wall effects it is necessary either to roughen the walls at the sand level during construction or ensure that the drainage system ends at least 600mm from the walls. It is preferable to take both precautions.

6. Inlet flow control

Inlet flow control by butterfly valve is advantageous if possible. It is not essential.

For further information:

Ellis, K.V., *Slow Sand Filtration*. CRC Critical Reviews in Environmental Control, 15, 4, 315-354, 1985.
Huisman, L. and Wood, W.E., *Slow Sand Filtration*, WHO, Geneva ,1974.
Slow Sand Filtration for Community Water Supply in Developing Countries: A Design and Construction Manual. IRC Technical Paper Series No.11, 1978.

Text: Ken Ellis Illustrations and design: Rod Shaw
WEDC, Loughborough University of Technology, Loughborough, Leicestershire LE11 3TU, UK.